Occurrence of deep non-volcanic tremors synchronized to earth tides

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Swarms of deep non-volcanic tremors occur with slow slip events along the subduction zone of the Philippine Sea plate in southwest Japan. These episodic events are considered to be linked in stress relaxation process in the transition zone of subducting plate interface. Tremor swarms often exhibit occurrence with a period of about 12 or 24 hours. Although it is easy to surmise that such periodicity arises from effects of the Earth tides caused by gravitational perturbations from the Moon and Sun, it has not yet been given quantitative explanations. We assume that tremors occur as thrust faulting at the subducting plate interface, and calculate the tidal stress at the central point of the epicenter distributions on the fault plane. Time series of Coulomb failure stress are well correlated to the tremor occurrences. The dominant period of tremor occurrence is consistent with that of tides. This is a strong evidence for the tidal origin. But, there is a few-hour advance of the tremor occurrence relative to the Coulomb failure stress. This indicates the simple threshold model is inappropriate for the tremor occurrence. Time series of shear stress rates are also well correlated to the tremor occurrences. There is a few-hour delay of the tremor occurrence relative to the shear stress rate.

The stress rate dependence and time delay of events can be reproduced by incorporating the rate- and state-dependent friction law. We apply the seismicity rate theory based on the rate- and state-dependent friction law to the tremor occurrence. We assume that the stress change in tremor patches is composed of the secular change due to the plate subduction, the transient change due to the slow slip event, and the periodic change due to the Earth tides. The periodic tremor occurrence is well reproduced by the seismicity rate calculated using the above stress change.

The result shows that the rate of transient stress to trigger the tremors is on the order of 1-10 kPa day, which is comparable to the rate of periodic tidal stress. The value of A times sigma, the fault constitutive constant times the effective normal stress, is on the order of 1 kPa and the standard error is on the order of 0.1 kPa. This is one to two orders of magnitude smaller than those obtained for earthquake swarm and afterslip. If we adopt 0.01 for A, the effective normal stress becomes on the order of 100 kPa in the transition zone. Otherwise, if we adopt 600 MPa for the effective normal stress, A becomes on the order of 0.0001 in the tremor source region. Since the value what we estimate is the product of A and sigma, we could not show that which value is smaller than other studies.

Observing deep non-volcanic tremors is therefore effective for monitoring the stress relaxation process in the transition zone.